STATE OF ILLINOIS

ILLINOIS COMMERCE COMMISSION

COMMONWEALTH EDISON COMPANY	:	
	:	
Application for a Certificate of Public Convenience and Necessity, pursuant to Section 8-406.1 of the Illinois Public Utilities Act, and an Order pursuant to Section 8-503 of Illinois Public Utilities Act, to Construct, Operate and Maintain a new 345 kilovolt transmission line in Ogle, DeKalb, Kane and DuPage Counties, Illinois	:	No. 13-0657

Rebuttal Testimony of

PETER A. VALBERG, PH.D.,

Principal, Gradient,

On behalf of

Commonwealth Edison Company

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I. INTRODUCTION

A. Witness Identification

Q. **Please state your name and business address.**

A. My name is Peter Valberg. My business address is 20 University Road, Cambridge, MA 02138.

Q. **By whom are you employed and in what capacity??**

A. I am a Principal at Gradient. Gradient is an environmental and risk science consulting firm known for our specialties in Toxicology, Epidemiology, Human Health Risk Assessment, Product Safety, Contaminant Fate and Transport, and Environmental/Forensic Chemistry.

Q. **Who are you testifying on behalf of in this proceeding?**

A. I am testifying on behalf of Commonwealth Edison Company ("ComEd").

B. Background and Qualifications

Q. **What are your duties and responsibilities in your present position?**

A. I specialize in the areas of inhalation toxicology, biological modeling of human exposure to environmental agents, and assessment of human health risks. Some of the specific agents I have studied extensively include air / soil / water pollutants, radio wave frequencies ("RF"), and power-line electric and magnetic fields ("EMF"). My primary duties and responsibilities include keeping abreast of scientific developments in human health risk assessment and preparing documents that review the status of current research as to what is known regarding potential health risks of human exposure to chemicals, ionizing radiation, and non-ionizing radiation.

Q. **Please describe your professional and educational background.**

A. I hold an A.B. degree, *summa cum laude,* in Physics and Mathematics from Taylor University, both M.A. and Ph.D. degrees in Physics from Harvard University, and an M.S. degree in Human Physiology from the Harvard University School of Public Health ("HSPH").

For 25 years, I served as a faculty member in the Department of Environmental Health at HSPH, where I researched and taught toxicology, cell biology, environmental health, and public health. One of the research grants I directed at HSPH was funded by the National Cancer Institute, and was on the topic of "Magnetic Field Effects on Macrophages" (where "macrophages" are a type of lung cell that cleans our lung surfaces of particles deposited in our respiratory tract from inhaled dust present in the air we breathe).

I have served on advisory panels for the National Institutes of Health ("NIH"), the Health Effects Institute, and the Environmental Protection Agency ("EPA"). I am a member of the International Society for Environmental Epidemiology, the Health Physics Society, the Bioelectromagnetics Society, and have participated in the Committee on Man and Radiation ("COMAR"). Through the Harvard Center for Risk Analysis, I served as a member of the "Harvard Advisory Committee on EMF and Human Health" as well as the "Peer Review Board on Cellular Technology and Human Health" during the time when those workgroups were active at HSPH. I assisted the Health Effects Institute in determining the feasibility of launching an EMF research program, and I have published a summary document on "EMF Mechanisms" in the journal Radiation Research. At the request of the International Congress on Radiation Research ("ICRR"),

I organized and chaired a symposium on "Physical aspects of EMF / RF effects on Biological Systems," at the 11th Annual ICRR meeting in Dublin, Ireland. I also helped organize a conference in the Boston area on "Childhood Leukemia: Electric and Magnetic Fields as Possible Risk Factors." A summary of this workshop was published in the journal *Environmental Health Perspectives*. I also worked with the World Health Organization studying the health effects of RF from cellular phones and base stations. The results of that project were also published in the journal *Environmental Health Perspectives*.

My resume is attached to my rebuttal testimony as ComEd Exhibit ("Ex.") 20.01. Also, ComEd Ex. 20.02 lists my testimony before regulatory boards on the issue of EMF health effects.

C. Purpose of Testimony

Q. **What are the purposes of your rebuttal testimony?**

A. I respond to the direct testimony submitted by the following intervenors: Jerry Drexler, Debra K. Hirschberg, William Lenschow, Jeffrey King, Robert Mason, Charles and Susan Payne, Jeffrey C. Payne, Kristine Pienkowski, Thomas Pienkowski, and John Tomasiewicz. Specifically, I was asked by ComEd to assess the potential health effects of EMF exposure related to ComEd's proposed Grand Prairie Gateway Transmission Line Project ("GPG Project" or "Project"), which involves constructing an approximately 60-mile long, 345 kilovolt ("kV") transmission line, and which is the subject of this Illinois Commerce Commission proceeding. I have read the testimony submitted by the above individuals, and in the following text, I identify the scientific research and

summary conclusions that address their concerns, both in a general way and in specific comments.

Q. **Please outline the components of your rebuttal testimony.**

A. Section I has summarized my qualifications. Section II provides an overview of EMF sources and Public Health. Section III summarizes applicable regulatory guidance and examples of expert opinion relating to potential health impacts from EMF exposure. Section IV summarizes the EMF levels calculated for the Project. Section V summarizes the conclusions of my analysis.

D. Summary of Conclusions

Q. **What conclusions have your reached?**

A. In brief, based on my review of (1) the current status of biological, public health, and medical research on the possible effects of power-line EMF on health, (2) the current scientific consensus documents and regulatory guidelines on allowable EMF exposures, and (3) the EMF levels predicted to be associated with the GPG Project, I conclude that the EMF that will be produced as a result of this Project would not be expected to have adverse public health effects. I gave consideration to the arguments raised by the direct testimony filed in this case concerning EMF health effects, but I did not find them persuasive.

E. Itemized Attachments to Rebuttal Testimony

Q. **Are you sponsoring any attachments to you testimony?**

A. Yes. As I noted above ComEd Ex. 20.01 is my resume and ComEd Ex. 20.02 is a list of my testimony before regulatory boards on the issue of EMF health effects.

II. OVERVIEW OF EMF DEFINITIONS, SOURCES, AND MAGNITUDES

Q. **Where does EMF come from?**

A. All matter contains electrically-charged particles. Most objects are electrically neutral because positive and negative charges are present in equal numbers. When the balance of electric charges is altered, we experience electrical effects, such as the static electricity attraction between a comb and our hair, or drawing sparks after walking on a synthetic rug in the wintertime. Electrical effects both in nature and in society's use of electric power (generation, transmission, consumption) produce EMF.

The work put into electrically charging something is measured by the *voltag*e. *Volts* represent the work-per-unit-charge (joules per coulomb), and the symbols are V for *volts*, or kV for *kilovolts* (1 kV = 1,000 V). Voltage is the "pressure" of the electricity, and is analogous to the pressure of water in a plumbing system. Electric charges push and pull on each other. Opposite charges *(e.g.*, + and –) attract and like charges *(e.g.*, + and +) repel. Scientists explain these forces exerted by charges by saying that each electric charge generates an *electric field* that exerts force on other nearby charges. That is, an electric field is a measure of force per unit charge (newtons per coulomb), but is usually expressed in units of *volts per meter* ("V/m") or *kilovolts per meter* ("kV/m").

When electric charges move, an electric *current* exists, and a current generates a *magnetic field*. Units of electric current are *amperes* ("A"), and current measures the "flow" of electricity, somewhat like the flow of water in a plumbing system. The current of moving electric charges produces a magnetic field that exerts force on other moving charges. That is, a magnetic field expresses the force per unit length of current-carrying wire (newtons per amp-meter), but is usually expressed in units of gauss (G) or

milligauss ("mG"). Another magnetic field unit is the tesla (T), where 1 T = 10,000 G, and thus, 1 μT = 10 mG.

Electric motors use magnetic-field forces to turn electric power into mechanical work. Conversely, power-plant generators rotate loops of wire through magnetic fields and convert mechanical energy into electric power. Most of the attention regarding possible health effects has focused on magnetic field exposures and not electric field exposures.

Q. **Where do people encounter magnetic fields in everyday life?**

A. Everyone is exposed to a wide variety of natural and man-made electric and magnetic fields. EMF fields can be slowly varying or steady (often called "DC" fields for fields produced by "direct current") or can vary in time (often called "AC" fields for fields produced by "alternating current"). When the time variation of interest corresponds to that of power line currents, *i.e.,* 60 changes per second, the fields may be called "60-Hz" EMF.

Man-made magnetic fields are common in everyday life. Many childhood toys contain magnets. "Permanent magnets" generate strong, steady magnetic fields. Typical toy magnets (*e.g.*, "refrigerator-door" magnets) produce 100,000 – 500,000 mG. Magnetic resonance imaging ("MRI") is a medical diagnostic procedure that puts humans in much larger fields (20,000,000 mG) and is preferred over an X-ray because of its safety. These are primarily "DC" or steady magnetic fields, but movement relative to the sources creates a time-changing magnetic field that can be similar to AC fields from power lines.

A magnetic field is produced by the earth's core, and it can be easily demonstrated with a compass needle, which is turned into alignment by the force exerted on it by the geomagnetic field. The size of the earth's magnetic field in North America is about 570 mG. Also, clouds in the atmosphere are always electrically charged (*i.e.*, they have an excess of positive or negative charges), and thus we are exposed to slowly varying electric fields (about 100 to 10,000 V/m) that occasionally discharge as lightning strikes. Knowing the strength of the earth's EMF provides a perspective on the size of power line electric and magnetic field measurements. The earth's steady electric and magnetic fields do not have the 60-cycles-per-second ("60-Hz") time variation characteristic of power line EMF, but are otherwise indistinguishable. For example, a magnet spinning at 60 Hz produces a 60-Hz magnetic field just like the magnetic field produced by 60-Hz power-line currents.

Electric power transmission lines, distribution lines, and electric wiring in buildings carry AC currents and voltages that change size and direction at 60 times per second, or at 60 Hz. These 60-Hz currents and voltages produce 60-Hz EMF. The size of the magnetic field is proportional to the current, and the size of the electric field is proportional to the voltage. Importantly, the size of both the electric and magnetic fields decreases rapidly with distance from the electrical wires. When EMFs are produced by different sources (*e.g.*, adjacent wires) the net EMF may be the sum total of both, or the net EMF may be less (that is, EMFs may add or partially cancel). Inside residences, typical baseline 60-Hz magnetic fields (away from appliances) range from 0.5 to 2.0 mG. These fields arise from electric appliances, outdoor distribution wiring, indoor wiring, and ground return pathways (often, currents on water pipes). The time-varying power

line magnetic fields add to or subtract from to the steady field of the earth (570 mG) to superimpose a slight time variation.

Higher magnetic field levels are found near operating appliances. For example, can openers, mixers, blenders, refrigerators, fluorescent lamps, electric ranges, clothes washers, toasters, portable heaters, vacuum cleaners, electric tools, and many other appliances produce magnetic fields of size 40 – 300 mG at distances of 1 foot.[1] Magnetic fields from personal-care appliances held within ½ foot (*e.g.*, electric shavers, hair dryers, massagers) can produce 60-Hz magnetic fields of 600 – 700 mG. In the school and work environment, copy machines, vending machines, video-display terminals, electric tools, lights, and motors are all sources of EMF exposure.

III. EXPERT OPINION AND REGULATORY GUIDANCE ABOUT EMF POWER LINE EXPOSURE

Q. **What is the state of the scientific knowledge about the health effects of exposure to power line EMF?**

A. Scientists have been looking at potential biological effects of power-line EMF for more than three decades. Over this period of time, the focus has been primarily on the magnetic field component. The three major lines of investigation have involved epidemiology, laboratory animal studies, and biological mechanism studies. The sum of scientific evidence currently available from a considerable amount of scientific research on EMF health effects and human experience with EMF does not establish that environmental levels of power-line EMF are hazardous to our health.

[1] National Institute of Environmental Health Sciences, Electric and Magnetic Fields Associated with the Use of Electric Power, Questions and Answers, NIH Publication 02-4493 (2002). Research Triangle Park, NC.

EMF epidemiology studies have received considerable attention. "Epidemiology" is a statistical science that tests for correlations between patterns of disease occurrence and patterns of human lifestyle, diet, occupation, environment, or exposure. An epidemiologic study published in 1979[2] suggested that living near electric power distribution lines was linked to an increased risk of childhood cancer. In this and subsequent epidemiology studies, the actual EMF levels that children had been exposed to were unknown, so researchers developed surrogates for past EMF exposures based, for example, on the proximity, number, and size of electric-utility distribution lines near the homes. In the initial 1979 study, the electric utility distribution line configuration near a home was called its "wire code," and homes with high wire codes (and presumably higher EMF levels) were found to be represented in a greater proportion of the leukemia cases as compared to the control children.

During the 35 years since this first study, a number of epidemiologic studies have examined associations between disease and various proxies of power line field strength (*e.g.*, the "wire code" classification of homes, the distance to power-line corridors, present-day measurements, the field strength calculated from power-line loading). If a correlation was detected, it was reported as "linking" power-line EMF to increased risk for the disease being studied. However, repeat studies often showed that the associations were weak and inconsistent. Moreover, the associations often disappeared when actual personal-monitor measured magnetic fields were substituted in place of other surrogate measures. It was found that some surrogates used for ranking EMF exposure also

[2] N. Wertheimer and E. Leeper, "Electrical Wiring Configurations and Childhood Cancer," *Am J. Epidem.* **109**: 273-284 (1979).

correlated with non-EMF factors such as traffic density, age of the home, rental *vs.* ownership, and assessed value of the home. Such "confounders" made it unlikely that the reported associations with cancer risk were actually an effect of EMF exposure *per se*. That is, statistical correlations do not isolate the EMF exposure as the "causal" factor in the associations reported.[3]

Q. **What are some of the important studies undertaken concerning the possible health risks that power-line EMF exposures pose to humans?**

A. Hundreds of EMF epidemiology and laboratory research studies have been published in the 35 years since the initial 1979 study reported a statistical correlation between residential "wire codes" and childhood leukemia. Generally, each study focuses on a particular hypothesis, and the range of possible investigations has been immense. Some of the most important work was done under the auspices of the National Institute of Environmental Health Sciences ("NIEHS"). The NIEHS had a program called "EMF RAPID," which funded laboratory research to determine what, if any, aspects of power-line magnetic fields (sometimes called extra-low-frequency EMF, or "ELF-EMF") interaction with biological systems had the potential to cause adverse disease outcomes. The conclusion of the NIEHS research program was summarized by NIEHS in 1999 as follows:[4]

> The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. ... No indication of increased leukemias in experimental animals has been observed. ... Virtually all of the laboratory

[3] Ahlbom A.; Cardis E.; Green A.; Linet M.; Savitz D.; Swerdlow A.; "Review of the Epidemiologic Literature on EMF and Health," Environ Health Perspect **109** (Suppl 6):911-33 (2001).

[4] National Institutes of Environmental Health Sciences (NIEHS), *Health Effects From Exposure to Power-Line Frequency Electric and Magnetic Fields*, NIH# 99-4493 (1999). Research Triangle Park, NC, at p. ii of Exec. Sum.

> evidence in animals and humans, and most of the mechanistic studies in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status.

There continues to be a lack of supporting laboratory evidence, or plausible biological mechanism support, for power-line EMF exposure leading to health effects.[5, 6]

Epidemiologic analyses have continued over the years, and the following list provides examples of prominent analyses, reviews, and / or summaries of this EMF literature. Notably, the epidemiological associations have not become stronger over time with the advent of larger, more recent studies. There remains considerable inconsistency among the epidemiology results, the levels of incremental risk are low, and often do not reach statistical significance.

- Ahlbom A, Day N, Feychting M, Roman E, Skinner J, *et al*., *Pooled Analysis of Magnetic Fields and Childhood Leukemia*,. Br. J. Cancer 83:692-8 (2000).: "When [we] pooled nine epidemiology studies, … [we] found a relative risk of 2.0 (1.27-3.13) for childhood leukemia in the children with average exposures of 4 mG or greater. For children with lower average exposures, no significant elevation of childhood leukemia was found in the pooled studies. … … The explanation for the elevated risk is unknown, but selection bias may have accounted for some of the increase."
- Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA, *A Pooled Analysis of Magnetic Fields, Wire Codes, and Childhood Leukemia, Childhood Leukemia-EMF Study Group*, Epidemiology 11:624-634 (2000).: "Summary estimates from 12 studies that supplied magnetic field measures exhibited little or no association of magnetic fields with leukemia when comparing 0.1– 0.2

[5] Boorman G.A., McCormick D.L.; Findlay J.C.; Hailey J.R.; Gauger J.R.; Johnson T.R.; et al., *Chronic Toxicity Oncogenicity Evaluation of 60 Hz (Power Frequency) Magnetic Fields in F344/N Rats*, Toxicol Pathol 27:267-78 (1999).; McCormick D.L.; Boorman G.A.; Findlay J.C.; Hailey J.R.; Johnson T.R.; Gauger J.R., et al. *Chronic Toxicity/Oncogenicity Evaluation of 60 Hz (Power Frequency) Magnetic Fields in B6C3F1 Mice*, Toxicol Pathol 27:279-85 (1999).; Boorman GA, McCormick DL, Ward JM, Haseman JK, Sills RC. *Magnetic fields and mammary cancer in rodents: a critical review and evaluation of published literature.* Radiat Res. 153(5 Pt 2):617-26 (2000).

[6] Swanson J., and Kheifets L. *Biophysical mechanisms: a component in the weight of evidence for the health effects of power-frequency electric and magnetic fields*. Radiation Research 165(4): 470–478 (2006).; World Health Organization. *Extremely Low Frequency Fields. Environmental Health Criteria* Monograph n1 238. World Health Organization: Geneva (2007).; Scientific Committee on Emerging and Newly Identified Health Risks. *Health Effects of Exposure to EMF*. SCENIHR on EMF (2009).

and 0.2– 0.3 microtesla (μT) categories with the 0–0.1 μT category, but the Mantel-Haenszel summary odds ratio comparing >0.3 μT to 0–0.1 μT was 1.7." "Based on a survey of household magnetic fields, an estimate of the U.S. population attributable fraction of childhood leukemia associated with residential exposure is 3%."

- Hatch EE, Kleinerman RA, Linet MS, Tarone RE, Kaune WT, Auvinen A, *et al., Do Confounding or Selection Factors of Residential Wiring Codes and Magnetic Fields Distort Findings of Electromagnetic Fields Studies?*, Epidemiol 11:189-98 (2000).: "Our recent large case-control study [638 cases, 620 controls] found little association between childhood acute lymphoblastic leukemia (ALL) and electric-power-line wire codes."

- Kleinerman RA, Kaune WT, Hatch EE, Wacholder S, Linet MS, et al. *Are Children Living Near High-Voltage Power Lines at Increased Risk of Acute Lymphoblastic Leukemia?*, Am. J. Epidemiol. 151:512-5 (2000).: "Neither distance nor exposure index was related to risk of childhood acute lymphoblastic leukemia, although both were associated with in-home magnetic field measurements. Residence near high-voltage lines did not increase risk."

- *UK Childhood Cancer Study Investigators, Childhood Cancer and Residential Proximity to Power Lines*, Brit. J. Cancer. 83:1573-1580 (2000): "Our results provide no evidence that proximity to electricity supply equipment or exposure to magnetic fields associated with such equipment is associated with an increased risk for the development of childhood leukemia nor any other childhood cancer."

- Kheifets L, Ahlbom A, Crespi CM, Draper G, Hagihara J, Lowenthal RM, *et al. Pooled analysis of recent studies on magnetic fields and childhood leukaemia.* Br. J. Cancer 103:1128-35 (2010).: "10,865 cases and 12,853 controls were pooled from 7 studies; 24-hr meas. or calculated MF; >3 mG, compared to MF <1 mG: OR=1.44 (n.s., CI 0.88–2.36), "the results are compatible with no effect [of EMF]. Overall, the association is weaker in the most recently conducted studies, but these studies are small and lack the methodological improvements needed to resolve the apparent association."

- Kroll ME, Swanson J, Vincent TJ, Draper GJ. *Childhood cancer and magnetic fields from high-voltage power lines in England and Wales: A case-control study.* Br. J. Cancer 103:1122-1127 (2010).: "For children born in England and Wales during 1962–1995; there were 28,968 complete matched case–control pairs [calculated fields for 58,162 total]. We found no statistically significant associations between childhood-cancer risks and estimated magnetic fields from high-voltage power lines near the child's home address at birth."

- Pedersen C, Raaschou-Nielsen O, Rod NH, Frei P, Poulsen AH, Johansen C, Schuz J. *Distance from residence to power line and risk of childhood leukemia: A population-based case-control study in Denmark.* Cancer Causes Control 25:

171-7 (2014).: "1,698 childhood leukemia cases were compared to 3,396 controls; exposure assessment used the distance between residence at birth and the nearest 132–400 kV overhead power line; children who lived 0–199 m from the nearest power line had OR=0.76 [0.40–1.45] when compared to children >600 m away. Overall distance to the nearest power line was not associated with a higher risk of childhood leukemia. We did not observe any association with close distance or further away."

- Bunch KJ, Keegan TJ, Swanson J, Vincent TJ, Murphy MFG. *Residential distance at birth from overhead high-voltage powerlines: Childhood cancer risk in Britain 1962-2008.* Br. J. Cancer doi : 10.1038 (2014): "16,630 leukemia cases 1962–2008 compared to 20,429 matched controls; calculated distances of mother's address at child's birth to power lines used as exposure metric. Odds ratio for leukemia, 0-200 m compared with >1,000 m over the whole period OR=1.12 (0.90–1.38) – not statistically significant. Over the whole period, there is no evidence of a distance effect for any of the three cancer groups."

- Elliott P, Shaddick G, Douglass M, de Hoogh K, Briggs DJ, Toledano MB. *Adult cancers near high-voltage overhead power lines.* Epidemiology 24(2):184-90.: "[Our] study included 7,823 leukemia, 6,781 brain/central nervous system cancers, 9,153 malignant melanoma, 29,202 female breast cancer cases, and 79,507 controls […] 15-74 years of age living within 1000 m of a high-voltage overhead power line." "We observed no meaningful excess risks and no trends of risk with magnetic field strength for the four cancers examined." "Our results do not support an epidemiologic association of adult cancers with residential magnetic fields in proximity to high-voltage overhead power lines."

Q. **Why are there differences among the various epidemiology reviews and studies?**

A. It is important to remember that the EMF epidemiology studies are just statistical correlations. There are various inherent problems with an "observational" approach that can give you a misleading result; thus, correlations shouldn't be accepted as a cause and effect link. Many of the authors make note of sources of error from selection bias, confounding, and exposure misclassification, which can give rise to a correlation in the absence of a causal link. The power line magnetic-field epidemiology has shown some statistical associations and scientists have struggled with whether such associations can really be interpreted to mean that there is a causal effect there. This is primarily why the

NIEHS initiated the EMF laboratory research program. The statistical results need to be interpreted in light of evidence from animal toxicology and mechanistic understanding.

That is, the EMF epidemiology studies triggered many laboratory studies where people took that same hypothesis into the lab and said: can environmental power-line electric or magnetic fields affect biology, can they alter processes in living cells, are they going to change molecules in such a way as to increase the risk of cancer or other diseases? Even after considerable effort and some promising leads, the laboratory evidence and mechanistic analysis have not supported the increments in risk suggested by the epidemiology studies. Some scientists put more emphasis on the statistical associations while others question why animal and test tube experiments have been unable to identify an EMF mechanism or a reproducible health problem in animals or human volunteers. The absence of support from such laboratory studies causes most scientists give less weight to the statistical studies.

Q. **What conclusions have been drawn from the laboratory and animal studies of EMF biological effects?**

A. Supporting evidence for an adverse effect of environmental power-line EMF exposure on health has not been forthcoming from laboratory animals exposed to EMF, or from mechanistic analysis of how EMF might cause an effect on living cells. To date, there is neither an accepted mechanism by which power line EMF can cause disease, nor is there any animal model in which lifetime exposure to even considerably elevated 60-Hz magnetic fields has reliably produced a disease or a pre-disease condition. This means that no one has been able to identify what aspect of EMF is the one we should potentially

avoid or regulate. If adverse health effects are to be expected, would they be due specifically to the frequency of oscillation, the electric fields, the magnetic fields, continuous exposure, intermittent exposure, peak fields, transients? In spite of many years of work, no firm evidence of adverse EMF effects has been found in the laboratory for any of the measures of EMF exposure that have been examined.

Q. **What is the present status of expert opinion on EMF health effects?**

A. At this point in time, a large volume of literature on the question of EMF health effects has been generated, representing the accumulation of many years of laboratory work and many years of human experience with EMF, *i.e.*, use of electricity for more than one hundred years. The scientific data on EMF and health have been assembled and reviewed by many independent consensus groups of research and health scientists. These groups and agencies include the International Commission on Non-Ionizing Radiation Protection, World Health Organization, the National Radiation Protection Board (UK), the National Academy of Sciences, the American Medical Association, the American Physical Society (the professional society for American physicists), the American Cancer Society, the Swedish National Health and Welfare Board, and the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). These "blue-ribbon" panels do not identify EMF from electric-power transmission lines as unsafe for nearby residents and public. The reports of these groups are voluminous, thorough, and even-handed. Some of the conclusions are illustrated below:

- American Cancer Society ("ACS"). The booklet "*Childhood Leukemia*," (2013) is available on the Internet, and it describes power-line EMF as an "unproven risk." The ACS also notes in "*Radiation Exposure and Cancer*" (2010) that: "It's not clear exactly how electromagnetic fields, a form of low-

energy, non-ionizing radiation, could increase cancer risk. Studies of lab animals have generally not found that magnetic fields increase the risk of cancer. The absence of a link in animal studies makes it less likely that human exposure to electromagnetic fields, at home or at work, affects cancer risk. The National Institute of Environmental Health Sciences (NIEHS) describes the scientific evidence suggesting that electromagnetic field exposures pose a health risk as 'weak.' "

- European Union, "*Extremely low frequency fields like those from power lines and household appliances*" (2009).: "Animal studies do not provide evidence that ELF magnetic field exposure alone causes tumours or enhances the growth of implanted tumours. Some inconsistent evidence has suggested that ELF magnetic fields might be co-carcinogenic (enhance the effects of known carcinogens) and that they may cause cancer-relevant biological changes in short-term animal studies. However, it was concluded that the data were not sufficient to challenge IARC's evaluation that the experimental evidence for carcinogenicity of ELF magnetic fields is inadequate."

- Institute of Electrical & Electronics Engineers ("IEEE"), *C95.6-2002 IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz. Prepared by Subcommittee 3, Safety Levels with Respect to Human Exposure, 0 to 3 kHz, of the International Committee on Electromagnetic Safety, Standards Coordinating Committee 28.* IEEE, Inc., Three Park Avenue, New York, NY 10016-5997, USA. (2002).: "Protection is to be afforded to individuals in the general population by limiting maximum permissible exposure (MPE) to magnetic field levels of 9,040 mG at 60-Hz power-line frequencies."

- International Agency for Research on Cancer ("IARC"), *Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. IARC Monographs on the Evaluation of Carcinogenic Risks in Humans*, 80:1-429 (2002).: "The association between childhood leukemia and high levels of magnetic fields is unlikely to be due to chance, but it may be affected by bias. In particular, selection bias may account for part of the association." (p. 332) [Thus] there is limited evidence in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to childhood leukemia. There is inadequate evidence in humans for the

carcinogenicity of extremely low-frequency magnetic fields in relation to all other cancers." (p. 338)[7]

- International Commission on Non-Ionizing Radiation Protection ("ICNIRP"), 2010 Fact Sheet: "[Two pooled epidemiological analyses] indicated that long-term exposure to 50-60 Hz magnetic fields might be associated with an increased risk of leukemia. … However, a combination of selection bias, some degree of confounding, and chance could possibly explain the results. In addition, no biophysical mechanism has been identified and the experimental results from animal and cellular laboratory studies do not support the notion that exposure to 50-60 Hz magnetic fields is a cause of childhood leukemia."

- National Academy of Sciences ("NAS"); National Research Council ("NRC"), *Research on Power-Frequency Fields Completed Under the Energy Policy Act of 1992. Final Report.* National Academy of Sciences Evaluation of the EMF RAPID Program, National Research Council, National Academy Press, June 1999, 107, Executive Summary p. 8.: "Results of the EMF-RAPID program do not support the contention that the use of electricity poses a major unrecognized public-health danger."

- National Cancer Institute ("NCI"), *"Magnetic Field Exposure and Cancer: Questions and Answers"*: "Currently, researchers conclude that there is limited evidence that magnetic fields from power lines cause childhood leukemia, and that there is inadequate evidence that these magnetic fields cause other cancers in children. Researchers have not found a consistent relationship between magnetic fields from power lines or appliances and childhood brain tumors."

- Scientific Committee on Emerging and Newly Identified Health Risks ("SCENIHR"), "Health Effects of EMF" (2013): "Some epidemiological studies are consistent with earlier findings of an increased risk of childhood leukemia with long-term average exposure to magnetic fields above 0.3 to 0.4 μT. However, as stated in [SCENIHR] previous opinions, no mechanisms have been identified that could explain these findings. The lack of experimental support and shortcomings identified for the epidemiological studies prevent a causal interpretation."

[7] In 2002, the International Agency for Research on Cancer (IARC) classified extremely low frequency (ELF) magnetic fields as Group 2B (possibly carcinogenic) on the IARC scale of carcinogenic risk to humans.

IARC uses the "possibly carcinogenic" category when talking about both cell phone radiofrequency ("RF") fields and power-line magnetic fields ("EMF"), and the IARC category 2B includes many ordinary exposures as "possible carcinogens," *e.g.*, coconut oil, gasoline, diesel fuel, fuel oil, mobile phones, "carpentry and joinery," coffee, carbon black (car tires), car-engine exhaust, surgical implants, talc-based body powder, iron supplement pills, mothballs, nickels, pickled vegetables, safrole tea, titanium dioxide, chloroform, for a total of 285 substances.

- World Health Organization ("WHO"), "Extremely Low Frequency Fields" (2007): "Uncertainties in the hazard assessment [of epidemiological studies] include the role that control selection bias and exposure misclassification might have on the observed relationship between magnetic fields and childhood leukemia. In addition, virtually all of the laboratory evidence and the mechanistic evidence fail to support a relationship between low-level ELF magnetic fields and changes in biological function or disease status. Thus, on balance, the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern."

Q. **Are you aware of whether any state, national, or international health organizations or regulatory bodies have adopted or recommended guidelines that limit people's EMF exposure that arises from electric power lines or other sources?**

A. The United States has no federal standards limiting occupational or residential exposure to 60-Hz EMF. I have provided two tables below that identify non-binding guidelines. The first of the two tables shows guidelines suggested by national and international health organizations. These are public-health-based levels, which are designed to protect the public against adverse health effects, but incorporate safety factors and should not be viewed as demarcation lines between safe and dangerous levels of EMF. The second table shows guidelines that have been adopted by various States in the U.S. These latter (State) guidelines have been designed to maintain the *status quo* of EMF on and near the transmission-line right-of-way ("ROW"), and are not health based.

60-Hz EMF Guidelines Established by Health & Safety Organizations		
Organization	**Magnetic Field (B)**	**Electric Field (E)**
American Conference of Governmental and Industrial Hygienists ("ACGIH") (occupational)	10,000 mG (a) 1,000 mG (b)	25 kV/m 1 kV/m
International Commission on Non-Ionizing Radiation Protection ("ICNIRP") (general public, continuous exposure)	2,000 mG	4.2 kV/m
Institute of Electrical and Electronics Engineers ("IEEE") Standard C 95.6 (general public, continuous exposure)	9,040 mG	5.0 kV/m
U.K. National Radiological Protection Board [adopted the ICNIRP guidelines]	2,000 mG	4.2 kV/m
Comparison to steady (DC) EMF, encountered as EMF outside the 60-Hz frequency range:		
[Earth's magnetic field, and atmospheric electric fields, static levels, typical of environmental exposure (c)]	[550 mG]	[0.2 kV/m to 12 kV/m]
[Magnetic Resonance Imaging (MRI) Scan, magnetic field intensity (c)]	[30,000,000 mG]	----
Key: mG = milligauss; kV/m = kilovolts per meter Notes: In the above table, on the ACGIH levels, (a) general worker, and (b) guideline for workers with cardiac pacemakers. Also, as to note (c), these EMF are steady fields, and do not vary in time at the characteristic power-line 60-cycles-per-second. However, if a person moves in the presence of these steady fields, the body experiences a time-varying field		

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State Transmission-Line 60-Hz EMF Standards and Guidelines				
State / Line Voltage	**Electric Field (E)**		**Magnetic Field (B)**	
	On ROW	Edge ROW	On ROW	Edge ROW
< 230 kV	8 kV/m	2 kV/m		150 mG [c]
Florida 230-500 kV	10 kV/m			200 mG [c]
>500 kV				250 mG [c]
Massachusetts		1.8 kV/m		85 mG
Minnesota	8 kV/m			
Montana	7.0 kV/m [a]	1.0 kV/m [b]		
New Jersey		3.0 kV/m		
New York	11.8 kV/m 11.0 kV/m [d] 7.0 kV/m [a]	1.6 kV/m		200 mG [c]
Oregon	9.0 kV/m			

Key: ROW = right-of-way; mG = milligauss; kV/m = kilovolts per meter

Notes: [a] Maximum for highway crossings
[b] May be waived by the landowner
[c] Maximum-load magnetic fields
[d] Maximum for private road crossings

IV. SUMMARY OF THE EMF CALCULATED FOR THE PROJECT

Q. **How did you assess the EMF impact of the proposed Project?**

A. I relied upon the EMF modeling performed by Engineers at ComEd.

Q. **What information did you and ComEd exchange?**

A. ComEd provided to me the results of calculations for electric and magnetic fields as a function of distance from the lines, and under various loading assumptions.

Q. **Are you comfortable that ComEd utilized an appropriate computer model and input assumptions?**

A. Yes. I reviewed their data and results, and then posed questions to ComEd on points that required clarification. Based upon my review, I am confident that the EMF modeling results reflect accurate calculations of EMFs along the GPG Project's 345kV transmission line corridors.

Q. **Please summarize the results of the EMF calculations**

A. For modeling EMFs, the lines were placed within the corridor at their existing or planned locations. The calculations were performed for locations where the lines make their closest approach to ground level (maximum sag). Magnetic field values change depending on current (power) carried by the lines. The modeling was done with the load conditions expected in 2018, should the GPG Project be built. The ROW corridor is typically 195 feet wide, and the ROW edge fields are projected to be 16 mG on one side and 13 mG on the other side. Within the ROW corridor, the peak field was projected to be 50 mG.

Q. **Please explain what conclusions on EMF levels you draw from these results.**

A. Several conclusions about EMF impact can be drawn from these results. First, in comparison to the international, national and state standards and guidelines listed earlier, the EMF levels (both the maximum levels and levels at the ROW edge) are considerably below what is permissible by the guidelines.

Q. **What are your conclusions with regard to impact of the Project EMF's on public health?**

A. On the basis of the EMF levels at issue and on the basis of the scientific literature and public health guidance available in this area, I conclude that the EMF that will be produced as a result of the GPG Project would not be expected to have adverse public health effects.

Q. **Would burying these lines underground eliminate exposure to power line EMF?**

A. No. The electric field would be shielded by the earth, but the magnetic field would not be. In fact, nearby the transmission-line corridor, the magnetic field would be expected to be larger than for overhead lines because the current-carrying conductors are closer to you (say, four feet below the surface) than for overhead lines (generally 40 to 50 feet above you).

V. SUMMARY OF ANALYSIS AND CONCLUSIONS

Q. **What is your summary of the current status of the science of EMF health effects?**

A. Thousands of studies have now examined the hypothesis that power-line EMF exposure can lead to biological effects, and potentially, adverse health impacts. Out of this vast number, some studies have reported results that can be interpreted as suggestive of power-line EMF being hazardous to human health, but the overall summary is that evidence for EMFs harming health is weak and inconsistent. It has not been possible to determine if the suggestive correlative results truly reflect a consistent and causal role for EMF, or whether they represent statistical and non-causal fluctuations, such as would be expected in any area of scientific investigation. There are many studies that have tried,

but failed, to replicate results suggesting hazard, and the lack of replication supports the conclusion that power-line EMF exposure is not likely to be hazardous. Even more scarce is evidence as to what aspects or types of EMF exposure, if any, are to be implicated in the health-risk associations.

No biological process that is consistent with known scientific knowledge, and by which EMF may plausibly cause harm to health, has been established. As a consequence, research to date does not provide policy-makers confidence that societal resources should be expended to reduce power-line EMF exposures.

Q. **Some researchers have proposed that policy makers adopt strategies of "prudent avoidance" of EMF exposure. What is your opinion of such proposals?**

A. Even if a strategy such as "prudent avoidance" or "the precautionary principle" were to be considered, policymakers are not able to specify what aspect of EMF should be "prudently avoided" or "cautiously regulated." It is easy to recommend that people move analog electric clocks away from their beds, for example, and there may be little harm in recommending that utilities consider no-cost or low-cost EMF mitigation measures. The majority of researchers, however, would suggest that extensive expenditures on EMF mitigation cannot be justified or guided by well-established scientific principles.

Generally, the assumption has been made that the intensity of time-averaged, 60-Hz magnetic fields should be the focus of mitigation. However, no scientific basis for this choice exists, and many other specific aspects of the "EMF environment" have been proposed as possible agents of biological activity, including: (1) Electric field intensity, (2) Magnetic fields with an intensity within a certain "window" of possible amplitudes,

(3) Peak magnetic fields, (4) 60-Hz magnetic fields with time-varying frequency, (5) Magnetic fields at harmonic frequencies (180 Hz, 300 Hz, *etc*.), (6) Only the power-line magnetic field that is parallel to the earth's static magnetic field, (7) Only magnetic fields of non-steady, or "intermittent" amplitude, (8) Magnetic fields with circular polarization, *i.e.*, rotating magnetic fields), (9) Magnetic fields of frequencies in "resonance" with certain biological ions such as calcium (Ca^{++}), sodium (Na^{+}), or potassium (K^{+}), (10) night-time magnetic fields that may interfere with melatonin secretion.[8] None of these aspects of EMFs, however, has been convincingly shown to be a likely risk factor, and thus there is no basis for committing significant resources to the development or implementation of avoidance strategies, because it is not known what specifically is to be avoided. Thus, the state of the science suggests that anxiety, time, energy, and money that might be spent mitigating power-line EMF would likely provide much greater health benefit if it were expended on addressing non-EMF health concerns. Other health-improvement activities are much more likely to produce a health benefit, including improved home safety, improved vehicle safety, improved pre-natal care, vaccination programs, better nutrition, more exercise, more frequent health checkups, encouragement of smoking cessation, drinking in moderation, weight reduction, blood pressure reduction, cholesterol reduction, and so forth.

Policymakers also need to consider that measures taken to reduce a hypothetical risk may lead to an increase in other, real risks. For example, EMFs from a transmission line can be reduced by moving the phase conductors closer together, but this increases the

[8] Valberg, P.A. *Designing EMF Experiments: What is Required to Characterize "EMF Exposure,"* Bioelectromagnetics 16:396-401 (1995).

risk of failure by flashover, and can make the tasks of electric-utility maintenance workers more hazardous. Likewise, underground lines may reduce EMFs in some locations, but this mitigation of hypothetical risk needs to be weighed against the ecological damage done to wetlands and wildlife habitat by the excavation necessary for underground lines.

In the final analysis, no human endeavor is without risk. Regardless of how many times one finds a safe outcome for any phenomenon, one cannot guarantee that the next investigation will not yield an adverse effect. This is an example of the fact that it is impossible to prove a negative. Even though it is not possible to provide proof that power-line EMFs carry no significant risk to human health, current science supports an absence of adverse public health effects from the power-line EMF that will be produced as a result of the GPG Project.

Q. **Even though scientific support for human health risk from power-line magnetic fields is insufficient, what about fears and concerns based on EMF health risk allegations?**

A. It has been recognized that media reports and special interest groups tend to promote fear and anxiety about health effects from power-line EMF,[9] but there is little that can be done to counteract these alarmist influences other than point to mainstream public-health agencies, as I have done here. Even for risks acknowledged to be "real," no human activity can be proved to be safe. Sometimes our best efforts to avoid risks often incur

[9] Witthöft M, Rubin GJ. 2013. "Are media warnings about the adverse health effects of modern life self-fulfilling? An experimental study on idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF)." *J Psychosom Res*. 74: 206-12.; Eldridge-Thomas B, Rubin GJ. 2103. "Idiopathic environmental intolerance attributed to electromagnetic fields: a content analysis of British newspaper reports." *PLoS One*. 8(6):e65713, Jun 14; doi: 10.1371.

other risks. Choosing to walk rather than drive eliminates some risks of injury or death, but in fact, walking may be more risky than driving in many circumstances. As another example, automotive airbags can save lives in a vehicle crash, but airbags can also deploy unnecessarily in situations where they increase the risk of injury or death.

Q. **Some testimony mentioned the idea that people may not feel "safe" when they can see or are near transmission lines.[10] Can you address the question of whether electric power transmission, distribution, and use are "safe"?**

A. Yes. As discussed in the previous question, certain information sources (*e.g.*, the Internet, media reports, information from general practitioners, relatives) can trigger and amplify fear-focused attention, fostering alarmist catch phrases (*e.g.*, "EMF are dangerous / harmful and must be strictly avoided"). This can result in safety-seeking and avoidance behavior regarding suspected exposures, which serves to further maintain a vicious circle of anxiety *via* negative reinforcement. The fact of the matter is, we as a society have used electricity in an increasing way since 1900 (*i.e.*, for more than 100 years), and yet, U.S. health statistics show a continual improvement in health over that time period. The U.S. *per capita* use of electric power has grown nearly 100-fold since 1900, and the ubiquitous EMF from power transmission, distribution, internal / external wiring in buildings, and home electric appliance use has likewise grown dramatically. Yet, our national health statistics do not show an increase in any disease over this period. This points to the conclusion that our society has used electric power (and its associated

[10] *See i.e.*, The Direct Testimony of Charles and Susan Payne at 3-4; The Direct Testimony of Jeffrey C. Payne at 2-4; Pienkowsli Ex. 1.0, 3:37-44; Pienkowski 2.0, 5:80-6-96; Pienkowski Ex. 3.0, 6:111-7:127; Mason Ex. 1.0, 4:48-56; Lenschow Ex. 1.0, 3:42-4:53; Drexeler Ex. 1.0, 3:43-4:50; School District Ex. 1.0, 3:45-4:74.

EMF) as "safely" as other technological advances, *e.g.*, indoor plumbing, central heating and air conditioning, public water supplies, telephones, and radio and television stations.

Q. **Some citizens have mentioned "stray voltage" concerns.[11] Is stray voltage a problem that arises with transmission lines?**

A. Generally not. Stray voltage is not "EMF," but rather, it refers to the minor electrical shocks you or animals may get when touching metallic equipment or metallic plumbing where there is an issue with faulty electrical grounding. Most often, stray voltage is not caused by transmission lines, but rather by poor wiring practices in distribution circuits and electrical wiring at the local house / farm level. Stray voltage has been long recognized as arising from electricity use, and a good stray voltage information resource has been written by the U.S. Department of Agriculture: "Effects of Electrical Voltage / Current on Farm Animals: How to Detect and Remedy Problems." It is possible that transmission lines running parallel and in close proximity to distribution lines can induce current (and therefore voltages) onto the neutral of an adjacent distribution line and, in some cases, can cause a voltage to appear between the neutral and an earth ground, which leads to another form of "stray voltage."

Q. **Does this complete your rebuttal testimony?**

A. Yes, it does.

[11] *See i.e.*, Lenschow Ex. 1.0, 3:42-4:53.